REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 9 Period--July 1 to September 30, 1943

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The material in this report consists largely of unpublished data ~~and should be kept confidential~~. It is made available in its present form for the convenience of the various State and Federal Agencies concerned with the preservation of stored grain from insect damage.

CORN STORAGE

Condition of Corn at Experimental Bin Sites

During the quarter the corn stored at all but five of the experimental bin sites has been disposed of owing to the heavy demand for corn. Those remaining are located in Henry, Story, and Montgomery Counties in Iowa, and Yellow Medicine and Nicollet Counties in Minnesota. Owing to the lack of corn available for experimental purposes this phase of the insect control program has had to be greatly curtailed. Headquarters have been transferred to Hutchinson, Kansas and future research work will be devoted largely to wheat storage problems. Results obtained with the fumigation of corn bins are included with the report on wheat fumigation.

WHEAT STORAGE

Condition of Wheat in Storage at Experimental Plots*

During July and August, the regular quarterly samples were taken from the bins on the experimental storage sites at both Jamestown, North Dakota, and Hutchinson, Kansas. Insect infestation was determined from the examination of average samples taken from each bin.

Insect populations in the Jamestown bins remained at a low level. Out of a total of 166 bins sampled, 4 bins (2.5%) were found to be infested with insects, and mites were found in 25 bins (15.1%).

At Hutchinson, there has been a tremendous increase in insect population since the May sampling. Out of 104 bins sampled, 86 per cent were found to be infested, 60 per cent grading weevily, as compared with 26 per cent infested and 5 per cent weevily at the time of the May sampling. The August samples were taken before the regularly scheduled annual fumigation was done late in August. Bins in the management series scheduled for turning and cleaning to control insects present a more serious problem, and it is doubtful if satisfactory control can be obtained by this method. A more detailed discussion of this phase of the work is given later in this report.

The comparative infestation at the two storage sites since the establishment of the project in 1940 is given in table 1.

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* Reported by H. H. Walkden and R. B. Schwitzgebel, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.

Table 1: -- Comparison of the insect infestation in wheat stored at Jamestown, North Dakota, and at Hutchinson, Kansas, October, 1941, to August, 1943.

Sampling period	Jamestown, North Dakota: No. bins sampled	Wee-vily bins (%)	Infested, not weevily (%)	Total infested (%)	Hutchinson, Kansas: No. bins sampled	Weevily bins (%)	Infested, not weevily (%)	Total infested (%)
1941								
Oct.-Nov.	139	1	18	19	144	9	31	40
1942								
Jan.-Feb.	133	1	6	7	135	16	53	69
Apr.-May	139	0	4	4	135	2	59	61
July-Aug.	142	0	6	6	124	0	43	43
Oct.-Nov.	146	0	1	1	133	58	21	79
1943								
Jan.-Feb.	152	0	0	0	144	33	21	54
Apr.-May	164	0	0.6	0.6	148	5	26	31
July-Aug.	166	0	2.5	2.5	114	60	26	86

Only three specimens of the rust-red grain beetle (Laemophloeus ferrugineus) were found in the Jamestown samples. At Hutchinson nine species of stored grain insects were found, as listed below, together with their comparative abundance.

Species	Average number per 1000-gm. sample
1. Flat grain beetle (Laemophloeus minutus Oliv.)	7.02
2. Sawtooth grain beetle (Oryzaephilus surinamensis L.) ...	4.97
3. Lesser grain borer (Rhyzopertha dominica F.)	0.55
4. Red flour beetle (Tribolium castaneum Hbst.)	0.10
5. Rice weevil (Sitophilus oryza L.)	0.08
6. Granary weevil (Sitophilus granarius L.)	0.01
7. Long-headed flour beetle (Latheticus oryzae Waterh.) ...	0.01
8. Cadelle (Tenebroides mauritanicus L.)	0.01
9. Hairy fungus beetle (Typhaea stercorea L.)	0.01

Effect of Turning and Cleaning Wheat on Insect Populations

During the quarter it became necessary to turn and clean, for the second time this year, those bins in the "turning and cleaning" group of the management series. The results are given in table 2. It should be borne in mind that after the wheat has been given its initial cleaning, subsequent turning and cleaning removes little but the free living insect forms. A total of three 1000-bushel bins and six 2740-bushel bins were turned and cleaned. From the table it may be seen that the percentage of insects removed by the cleaning operation varied from 49 to 93 per cent of the bran bugs and from zero to 100 per cent of the weevils, the average for the whole series of bins being 78 per cent of the bran bugs and 31 per cent of the weevils. The low percentage reduction in the weevil population makes this method of insect control of doubtful value, and past experience indicates that bins so treated continue to give trouble. It is expected that a majority of these bins will require fumigation before winter, thus eliminating them from this series. As a means of controlling insects in wheat stored in steel bins, turning and cleaning the grain gives no promise of being of any practical value.

Table 2: -- Insect populations in wheat stored in steel bins, before and after turning and cleaning. Hutchinson, Kansas, September, 1943

Bin	Capacity in bu.	Before turning and cleaning: Bran* bugs	Before turning and cleaning: Weevils**	After turning and cleaning: No./M grams: Bran bugs	After turning and cleaning: No./M grams: Weevils	After turning and cleaning: % removed: Bran bugs	After turning and cleaning: % removed: Weevils	Total insects removed (%)
2-15	1000	133	18	68	35	49	increase	32
1-14	1000	137	8	14	1	90	88	89
3-15	1000	101	22	30	8	70	64	69
8-10	2740	299	2	91	0	70	100	70
8-11	2740	40	24	10	24	75	0	47
5-7	2740	122	20	15	3	88	85	87
5-8	2740	25	3	4	3	84	0	75
6-11	2740	80	4	8	3	90	25	87
11-8	2740	211	6	14	0	93	100	93
Totals		1148	107	253	74			
Averages						78	31	74

* Sawtooth grain beetle, Flat grain beetle, and red flour beetle.
** Rice weevil and lesser grain borer.

Summer Distribution of Insects Within Bins

As noted in a previous report, infestation is being obtained on the distribution of the insects within the grain mass in wheat stored in steel bins. During the August sampling, the individual probe samples composing the average sample were examined separately to get additional data on the summer distribution of the insect populations within the bins. These data are presented in table 3. A total of 72 bins were sampled, keeping the individual probes separate, and of this number 14 were not infested and are not included in the table. In the individual probe samples, the insect infestation ranged from zero to 205 insects per 1000 grams of wheat, while in the average samples the range was from zero to 74.4 insects per 1000 grams. Sixty-one per cent of the insects occurred in the upper half of the bins as compared with 81 per cent at the time of the May sampling. The greatest numbers of insects were found in the centers of the bins, with those in the south quadrants next in abundance.

Table 3: -- Quarterly sampling, Hutchinson, Kansas, July-August, 1943. Intensity of infestation in individual probe samples composing the 10-probe average sample.

Bin No.	Locations and numbers of insects per 1000 grams															Average sample
	Center		North		East		South		West		Totals					
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Total			
2-12	100	120	64	80	60	96	68	62	52	48	344	406	750			74.4
12-1	167	205	39	21	27	29	57	37	56	48	346	340	686			68.6
9-5	75	65	17	33	27	62	22	133	28	114	169	407	576			57.6
3-10	122	58	56	22	28	72	64	50	38	22	308	224	532			53.2
3-12	78	66	36	48	6	66	18	40	30	54	168	274	442			44.2
3-13	62	56	32	16	46	22	36	28	56	22	232	144	376			37.6
3-11	66	18	8	34	64	68	24	26	22	30	184	176	360			36.0
4-12	66	46	48	28	24	10	48	14	44	16	230	114	344			34.4
10-5	108	66	24	2	30	6	71	10	13	4	246	88	334			33.4
9-4	53	6	57	30	25	54	26	21	28	4	189	115	304			30.4
8-10	52	11	30	16	41	14	37	38	28	35	188	114	302			30.2
9-6	84	4	48	3	47	13	55	25	21	0	255	45	300			30.0
11-8	64	21	21	2	15	7	32	37	47	15	179	82	261			26.1
1-14	18	18	32	22	12	46	34	36	10	32	106	154	260			26.0
8-9	81	4	16	0	20	1	57	11	40	13	214	29	243			24.3
8-4	53	1	26	8	36	1	34	7	41	4	190	21	211			21.1
6-8	30	2	20	1	32	1	53	8	40	3	175	15	190			19.0
3-15	54	62	8	14	18	6	2	6	14	4	96	92	188			18.8
2-15	24	8	6	14	26	10	22	26	18	18	96	76	172			17.2
6-2	42	2	12	17	33	3	8	20	14	10	109	52	161			16.1
5-1	52	14	8	14	5	5	16	14	12	0	93	47	140			14.0
12-11	30	28	14	16	12	4	10	10	6	4	72	62	134			13.4
8-5	52	0	27	1	33	1	8	2	7	2	127	6	133			13.3
12-12	6	2	14	2	24	8	18	6	16	24	78	42	120			12.0
11-2	30	0	15	0	8	3	9	23	15	3	77	29	106			10.6

(Continued)

Table 3, (continued)

Bin No.	Locations and numbers of insects per 1000 grams															Average sample
	Center		North		East		South		West		Totals					
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Total			
5-6	11	0	8	0	1	1	56	0	1	0	77	1	78	7.8		
8-8	3	0	2	1	19	1	21	4	18	2	63	8	71	7.1		
11-4	3	0	1	0	0	0	50	9	3	0	57	9	66	6.6		
6-11	16	0	12	0	14	0	8	2	9	0	59	2	61	6.1		
5-7	10	0	5	2	19	4	14	0	4	0	52	6	58	5.8		
6-4	3	1	2	0	1	0	42	1	0	0	48	2	50	5.0		
11-11	17	0	4	0	4	1	1	3	8	1	34	5	39	3.9		
8-11	4	2	3	0	3	0	4	2	19	1	33	5	38	3.8		
5-2	5	0	3	5	6	1	7	2	1	3	22	11	33	3.3		
12-10	12	0	8	0	3	0	6	0	2	0	31	0	31	3.1		
9-1	4	0	1	0	0	0	17	0	9	0	31	0	31	3.1		
1-2	10	12	0	2	2	0	2	0	2	0	16	14	30	3.0		
12-2	3	1	0	0	0	1	17	0	5	2	25	4	29	2.9		
5-8	5	0	0	2	5	0	1	6	7	0	18	8	26	2.6		
11-10	14	0	3	0	0	0	2	0	1	2	20	2	22	2.2		
6-7	5	1	3	0	2	0	7	0	2	0	19	1	20	2.0		
7-5	6	0	0	0	0	1	1	0	9	1	16	2	18	1.8		
3-14	2	4	0	2	6	0	2	0	0	0	10	6	16	1.6		
6-1	3	3	0	0	1	0	3	3	0	0	7	6	13	1.3		
10-1	6	0	0	0	0	0	6	0	0	0	12	0	12	1.2		
6-3	4	0	1	1	0	0	5	0	0	1	10	2	12	1.2		
8-7	0	0	3	0	2	0	0	0	5	0	10	0	10	1.0		
10-4	1	1	0	1	0	0	2	2	2	0	5	4	9	0.9		
7-10	1	2	1	0	1	0	3	0	0	1	6	3	9	0.9		
½-2	0	2	0	0	2	0	2	0	0	2	4	4	8	0.8		

(continued)

Table 3, (continued).

Bin No.	Locations and numbers of insects per 1000 grams															Average Sample
	Center		North		East		South		West		Totals					
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Total			
10-2	7	0	0	0	0	0	0	0	0	0	7	0	7			0.7
1-3	2	0	0	0	2	0	0	2	0	0	4	2	6			0.6
12-8	0	0	0	0	3	0	0	0	0	3	4	3	6			0.6
11-9	0	0	0	0	1	0	1	0	3	0	5	0	5			0.5
7-9	0	0	3	0	1	0	0	0	0	0	4	0	4			0.4
½-10	2	0	0	0	0	0	0	0	0	0	2	0	2			0.2
7-8	0	0	0	0	0	0	0	0	2	0	2	0	2			0.2
Totals	1728	912	741	460	797	618	1109	726	808	548	5183	3264	8447			
Per cent of total	20.4	10.8	8.8	5.4	9.4	7.3	13.1	8.6	9.6	6.5	61.4	38.6				

Experimental Fumigation of Wheat and Corn.

Experimental fumigation of wheat and corn has been continued during the quarter. Tests with carbon tetrachloride alone and various mixtures of carbon tetrachloride with ethide, chloropicrin, methylallyl chloride, ethylene dichloride, and carbon bisulphide have been conducted at Boone, Iowa, and Hutchinson, Kansas. The results of these tests are presented in tables 4 and 5.

B-methylallyl chloride applied at the rate of two pounds per 1000 bushels, using carbon tetrachloride as a carrier, gave satisfactory results in both wheat and corn.

Ethide performed well at dosages of one pound per 1000 bushels with carbon tetrachloride as a carrier in corn, while in wheat a dosage of two pounds per 1000 bushels is indicated.

Chloropicrin gave better results in the tests with corn than those with wheat when carbon tetrachloride was used as a carrier. Ethylene dichloride appears to be a poor carrier for chloropicrin.

The mixture of carbon bisulphide, 20 per cent, and carbon tetrachloride, 80 per cent, continued to give good results when applied in dosages as low as two gallons per 1000 bushels.

Further tests with the ethylene dichloride-carbon tetrachloride mixture 3-1 confirmed the previously determined dosage for wheat of four gallons per 1000 bushels in caulked steel bins. A dosage of six gallons per 1000 bushels is indicated for sorghum.

Additional tests were made with carbon tetrachloride alone. Better results were obtained in wheat than in corn at dosages of two gallons per 1000 bushels. The one- and two-gallon dosages were run in the Boone, Iowa, corn bins as a check on the effectiveness of ethide, B-methylallyl chloride, and chloropicrin. At one gallon per 1000 bushels, carbon tetrachloride gave an average kill of 56 per cent, while at two gallons per 1000 bushels the kill rose to 76 per cent. The addition of the various materials as indicated in table 5 increased the mortality as shown. It would appear that carbon tetrachloride alone is an effective fumigant, but its effectiveness against different species varies considerably, as do the other materials used in the Boone tests, as shown in table 6. From this table it may be seen that the resistance of the different species to the various fumigants is quite constant--the sawtooth grain beetle being least resistant, with the red flour beetle, lesser grain borer, and rice weevil increasingly resistant in the order named. Approximately 51,000 insects were used in the experimental fumigation of the corn at Boone, Iowa.

Table 4: -- Results of experimental fumigation of wheat stored in steel bins Hutchinson, Kansas

Fumigant	Bin No.	Capacity (bu.)	Dosage per 1000 bu. (gal.)	Mortality: Probes	Mortality: Native population	Remarks
B-methylallyl chloride 16% in carbon tetrachloride	1-6	1000	2	99	100	Floor, walls caulked
	1-7	1000	2	100	99	do
	10-7	2000	2	100	--	do
	10-8	2000	2	100	--	do
	9-12	2740	1.5	100	--	do
B-methylallyl chloride 20% in carbon tetrachloride	9-11	2740	1.5	100	--	do
B-methylallyl chloride 25% in carbon tetrachloride	3-8	1000	1.5	100	94	do
	3-9	1000	1.5	100	98	do
	9-10	2740	1.5	100	--	do
Ethide 1 lb. in carbon tetrachloride to make 1 gal.	2-4	1000	2	100	100	do
	2-5	1000	2	100	100	do
Ethide 1.5 lbs. in carbon tetrachloride to make 1 gal.	2-6	1000	2	100	99	do
	2-7	1000	2	100	100	do
Ethide 2 lbs. in carbon tetrachloride to make 1 gal.	1-1	1000	1.5	100	92	do
	3-5	1000	1.5	100	89	do
	5-3	2740	1	100	--	do
	12-9	2740	1.5	100	--	do
Ethide 2.5 lbs. in carbon tetrachloride to make 1 gal.	2-8	1000	1	100	81	do
	2-9	1000	1	96	60	do
Ethide 3 lbs. in carbon tetrachloride to make 1 gal.	1-12	1000	1	96	76	do
	1-13	1000	1	100	96	do
Chloropicrin 2 lbs in carbon tetrachloride to make 1 gal.	2-13	1000	1.25	89	98	do
	3-4	1000	1.5	100	76	do

(continued)

Table 4, (continued)

Fumigant	Bin No.	Capacity (bu.)	Dosage per 1000 bu. (gal.)	Mortality: Probes	Mortality: Native population	Remarks
Chloropicrin 2 lbs in ethylene dichloride to make 1 gal.	4-8	1000	1	75	40	Floor, walls caulked
	4-9	1000	1	64	20	do
Chloropicrin 2.5 lbs. in ethylene dichloride to make 1 gal.	4-6	1000	1	98	70	do
	4-7	1000	1	77	74	do
Carbon bisulphide 20%, carbon tetrachloride 80%	9-8	1500	1.5	100	88	do
	11-6	2740	1.5	100	--	Floor only caulked
	3-6	1000	2	100	98	Floor, walls caulked
	3-7	1000	2	100	100	do
	4-15	1250	2	98	--	do
	9-8	1500	2	100	--	do
	10-7	2000	2	100	--	do
	11-6	2740	2	100	--	Floor only caulked
	9-12	2740	2	99	--	Floor, walls caulked
	6-13	4000	2	99	--	do
Ethylene dichloride 75%, carbon tetrachloride 25% (Dowfume 75)	*6-9	2740	2.5	96	100	do
	*4-14	1000	3	100	100	do
	2-12	1000	4	100	97	do
	3-12	1000	4	100	99	do
	1-10	1000	4	--	100	do
	1-11	1000	4	--	100	do
	2-10	1000	4	--	100	do
	2-11	1000	4	--	100	do
	3-13	1000	4	--	99	do
	½-7	1000	4	100	93	Perforated floor
	½-8	1000	4	98	95	do
	9-1	2740	4	100	99	Floor, walls caulked
	10-1	2740	4	96	99	do
	10-2	2740	4	100	100	do
	11-1	2740	4	100	100	Perforated ventilator tube
	½-14	1000	6	--	91	Sorghum
Carbon tetrachloride alone (12.5% moisture)	1-8	1000	2	100	99	Floor, walls caulked
	1-9	1000	2	100	96	do
(do)	½-9	1000	2	100	--	do
(do)	½-10	1000	2	100	--	do
(12% moisture)	4-13	1000	2	100	--	do
	4-16	1000	2	100	--	do
(9% moisture)	½-3	1000	2	100	--	do
(do)	½-6	1000	2	100	--	do
	1-4	1000	2	99	--	do
	9-9	1500	1.5	100	100	do
	11-7	2740	1.5	100	--	Floor only caulked

* After turning and cleaning.

Table 5: -- Results of experimental fumigation of shelled corn in steel bins, Boone, Iowa. (Uncaulked bins)

Fumigant	Bin No.	Capacity (bu.)	Date treated	Dosage per M bu. (gals.)	Mortality (%)
B-methylallyl chloride 1.4 lbs. in carbon tetrachloride to make 2 gallons (9% mixture)	299	2740	7/29/43	2	90.0
	414	2740	7/30/43	2	78.7
	43	2000	7/30/43	2	88.0
	46	2000	7/29/43	2	83.9
B-methylallyl chloride 1.9 lbs. in carbon tetrachloride to make 2 gals. (12.5% mixture)	300	2740	7/29/43	2	98.6
	305	2740	7/30/43	2	96.2
	42	2000	7/29/43	2	83.8
	47	2000	7/30/43	2	91.2
B-methylallyl chloride 2.8 lbs. in carbon tetrachloride to make 2 gallons (16% mixture)	409	2740	7/29/43	2	96.5
	41	2000	7/29/43	2	90.2
	48	2000	7/30/43	2	95.4
Ethide 1 lb. in carbon tetrachloride to make 1 gallon	299	2740	9/ 6/43	1	94.2
	47	2000	9/ 6/43	1	96.7
	48	2000	9/ 6/43	1	96.0
Ethide 1 lb. in carbon tetrachloride to make 2 gallons	300	2740	9/ 6/43	2	99.8
	43	2000	9/ 6/43	2	98.0
	46	2000	9/ 6/43	2	99.3
Chloropicrin 1 lb. in carbon tetrachloride to make 1 gallon	299	2740	9/13/43	1	100.0
	47	2000	9/13/43	1	100.0
	48	2000	9/13/43	1	100.0
Chloropicrin 1 lb. in carbon tetrachloride to make 2 gallons	300	2740	9/13/43	2	100.0
	43	2000	9/13/43	2	100.0
	46	2000	9/13/43	2	100.0
Carbon tetrachloride, alone	409	2740	9/ 6/43	1	48.2
	409	2740	9/13/43	1	64.0
	42	2000	9/ 6/43	1	56.9
	42	2000	9/13/43	1	55.7
	305	2740	9/ 6/43	2	70.6
	305	2740	9/13/43	2	83.2
	41	2000	9/ 6/43	2	74.5
	41	2000	9/13/43	2	75.7

Table 6: -- Comparative resistance to fumigants of different stored grain insects used as check insects in fumigation of shelled corn stored in steel bins, Boone, Iowa.

Fumigant	Dosage per M bu. (gal.)	Per cent survival			
		Sawtooth grain beetle	Red flour beetle	Lesser grain borer	Rice weevil
Carbon tetrachloride, alone	1	13.4	31.5	41.8	57.9
Carbon tetrachloride, alone	2	5.1	9.8	23.1	40.2
Ethide, 1 lb., in carbon tetrachloride to make 1 gallon	1	0	2.9	2.5	6.9
Ethide, 1 lb., in carbon tetrachloride to make 2 gallons	2	0	0.3	0.4	1.7
B-methylallyl chloride 1.4 lbs. in CCl_4 to make 2 gallons	2	7.7	13.3	--	18.3
B-methylallyl chloride 1.9 lbs. in CCl_4 to make 2 gallons	2	2.5	8.5		12.4
B-methylallyl chloride 2.8 lbs. in CCl_4 to make 2 gallons	2	2.9	8.2		7.3

Effect of Fumigants on Germination and Baking and Milling Qualities of Wheat*

In previous experiments wheat samples of 11.5% moisture content, fumigated with normal dosages of our common grain fumigants, showed no significant loss in germination after a period of 3 months and there were no significant differences in milling or baking values. Samples treated with dosages of 20 pounds of methyl bromide and 20 pounds of chloropicrin per 1,000 bushels showed a gradual decrease in germination and at the end of 3 months the germination had dropped from 97 to 15 and 73% respectively. Baking tests showed a significant reduction in loaf volume in the case of the methyl bromide treated wheat the germination of which had been reduced to 15%.

Since it is evident from previous tests that the moisture content of the grain is the most important factor controlling injury from fumigants, the experiment was repeated using grain with a moisture content of 10.5%, 12.5%, and 14%.

Samples of each type of wheat were fumigated for 24 hours with methyl bromide, chloropicrin, hydrocyanic acid, carbon disulfide, carbon disulfide-carbon tetrachloride 1-4 mixture, ethylene dichloride-carbon tetrachloride 3-1 mixture, Ethide-carbon tetrachloride mixture, chloropicrin-carbon tetrachloride mixture and ethylene dichloride - carbon tetrachloride-methyl bromide mixture.

One lot of each sample was aerated and stored in a cotton bag so that aeration would continue, while the other lot was held in the tightly sealed container in which it was fumigated. Samples were taken after 1 week and are being taken at monthly intervals for germination tests, baking tests, etc.

The results of germination tests to date are given in table 7.

Normal dosages of all fumigants were used with the exception of methyl bromide and chloropicrin, where a 40 pound dosage of each chemical was used to obtain an immediate kill of the germ.

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* Reported by R. T. Cotton and J. C. Frankenfeld, United States Department of Agriculture, Bureau of Entomology and Plant Quarantine in cooperation with the Milling Department of Kansas State College.

Table 7: -- Effect of fumigants on germination of wheat as influenced by dosage, grain moisture, length of exposure, etc.

Fumigant	Dosage per 1000 bushels	Moisture content of grain (%)	% germination of aerated sample after 1 week	% germination of aerated sample after 1 month	% germination of non-aerated sample after 1 week	% germination of non-aerated sample after 1 month
Check		10.5	87	96		
do		12.5	59	98		
do		14.0	89	89		
Methyl bromide	40 lbs.	10.5			5	2*
do	40 lbs.	12.5			0	0*
do	40 lbs.	14.0			0	0*
Chloropicrin	40 lbs.	10.5			0	3*
do	40 lbs.	12.5			0	10*
do	40 lbs.	14.0			0	10*
Cyanogas	15 lbs.	10.5	91	97		97
do	15 lbs.	12.5	61	94		92
do	15 lbs.	14.0	86	95		92
Ethylene dichloride-carbon tetrachloride (3-1)	6 gals.	10.5	88	95		96
do	6 gals.	12.5	64	94		93
do	6 gals.	14.0	89	93		90
Carbon disulfide	3 gals.	10.5	90	95		95
do	3 gals.	12.5	65	94		87
do	3 gals.	14.0	85	93		77
Carbon disulfide-carbon tetrachloride (1-4 mixture)	3 gals.	10.5	89	97		93
do	3 gals.	12.5%	62	95		95
do	3 gals.	14.0	90	92		86
do	6 gals.	10.5	90	95		89
do	6 gals.	12.5	68	95		87
do	6 gals.	14.0	88	93		79
3 lbs. Ethide in carbon tetrachloride to make 1 gal.	1 gal.	10.5	86	96		93
do	1 gal.	12.5	68	95		87
do	1 gal.	14.0	90	93		82
3 lbs. Chloropicrin in CCl_4 to make 1 gallon	1 gal.	10.5	88	96		76
do	1 gal.	12.5	56	89		78
do	1 gal.	14.0	62	64		39
Dowfume Br 10	2 gals.	10.5	86	94		91
do	2 gals.	12.5	45	93		75
do	2 gals.	14.0	81	92		61

* These heavily fumigated samples were not held in tightly sealed containers after the 1st month when germination was apparently completely killed.

Normal dosages of the fumigants used in the experiment caused no injury to germination, when the wheat was aerated after the 24-hour exposure period, with the exception of the chloropicrin - carbon tetrachloride mixture which caused damage to the germination of the 14% moisture wheat. At the end of 1 month the germination was reduced to 64%. The low germination of the 12.5% moisture wheat at the end of 1 week was due to the fact that it was newly harvested wheat and the germination did not reach its maximum until some time had elapsed.

In the case of the non-aerated samples, germination damage at the end of 1 month was evident in the case of all three moisture variable wheats but was most pronounced in the case of the 14% moisture wheat where the germination was reduced to 39%.

With Dowfume Br 10 germination was reduced to 61% in the 14% wheat and 75% with the 12.5% wheat.

With carbon disulfide germination was reduced to 77% in the 14% wheat and 87% with the 12.5% wheat.

Slight injury was also obtained with mixtures containing carbon disulfide with 14% wheat and with all moisture wheats when a 6 gallon dosage was used.

Baking Tests

Baking tests were made only with the wheats showing nearly complete germination damage, i. e., those fumigated with 40 pound dosages of methyl bromide and chloropicrin. Data indicating the effect on loaf volume are given in table 8.

Table 8: -- Effect of germination damage on loaf volume.

Treatment of wheat	Grain moisture %	Protein	Percent germination	Loaf volume
40 lbs. methyl bromide for 24 hrs.	10.5	13.3	2	800
40 lbs. chloropicrin for 24 hrs.	10.5	13.3	3	770
Check untreated	10.5	13.3	96	810
40 lbs. methyl bromide for 24 hrs.	12.5	11	0	625
40 lbs. chloropicrin for 24 hrs.	12.5	11	10	542
Check	12.5	11	96	750
40 lbs. methyl bromide for 24 hrs.	14.0	10.5	0	585
40 lbs. chloropicrin for 24 hrs.	14.0	10.5	10	638
Check	14.0	10.5	96	683

Flour made from the fumigated wheat in all cases retained a strong odor even though the wheat was allowed to aerate for approximately 6 weeks after treatment.

The data of table 8 indicate that fumigation of the wheat with heavy dosages of both methyl bromide and chloropicrin causes a reduction in loaf volume except in the case of the low moisture and high protein wheat where the difference in loaf volume is not great enough to be significant.

Until further tests can be made it is unsafe to attempt to draw conclusions as to the exact cause of the reduction in loaf volume.

Tests of the 12.5% wheats by Dr. Davidson indicate that in the fumigated wheats the catalase is damaged. Germ damage appears to be correlated with the reduction in baking values in some cases, but not in all.

Effect of Moisture and Temperature on the Reproduction of the Granary and Rice Weevil*

On pages 23 to 28 of Report No. 8 a discussion was given relative to the survival of the granary and rice weevils reared in 12, 13, and 14% moisture wheat at 80° and 85° F. Due to the fact that the emergence of progeny of these two insects extends over a longer period than the established time for the survival of the original adults, the discussion on the effect of moisture and temperature on reproduction was omitted.

In order to obtain an accurate measure of the reproduction of the granary and rice weevil, the grain to which the original adults are exposed, is removed every two weeks and placed in pint mason jars. As soon as emergence starts, these lots are examined daily and the adult weevil are removed and counted. By removing the adults daily the chances of any reproduction by these progeny is prevented, so that the number of weevil obtained from these lots represent the actual reproduction by the original adults used in the tests.

It will be noted from the data of table 9 that the number of progeny of granary weevil increases with the increase in the moisture content of the wheat. At a constant temperature of 80° F., the number of progeny produced by 100 adult granary weevil over a period of 19 weeks, in 12, 13, and 14% moisture wheat was 5089, 9321, and 10,950 respectively; and at 85° F. the number of progeny was 4053, 6718, and 8047. In general, the greatest reproduction takes place between the 4th and 9th week of the life of the weevil. After the 9th week reproduction gradually decreases in all lots until by the end of the 19th week it is practically negligible. The decline in reproduction as shown by the biweekly infested lots, is more pronounced in the lower moisture wheat, in both the 80° and 85° F. series.

To date, tests have been completed in 12, 13, and 14% moisture wheat at temperatures of 70°, 75°, 80°, and 85° F. and the total number of progeny recovered from these tests are summarized in table 10. In Report No. 8, pages 29 to 31, it was noted that at 70° F. and 75° F., greatest reproduction of granary weevil occurred in 13% moisture wheat, and it was assumed that at these temperatures 13% wheat represented a more nearly optimum condition for the granary weevil. When, however, the temperature is increased to 80° and 85° F., greatest reproduction occurred in the 14% moisture wheat, indicating that as the temperature is increased optimum conditions for reproduction demands an increase in the moisture content of the grain. This condition, although far from being definitely established, is further emphasized by the general decrease in reproduction when the temperature is raised to 85° F. Although the greatest reproduction took place in 14% wheat it was considerably less than that occurring in 14% wheat at 80° F.

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* Reported by R. T. Cotton and J. C. Frankenfeld.

Table 9: -- Showing the biweekly reproduction of granary weevil in 12, 13, and 14% moisture wheat at 80° and 85° F.

Moisture content of wheat	Number of progeny produced at 80° F. during: 1st week	2nd & 3rd week	4th & 5th week	6th & 7th week	8th & 9th week	10th & 11th week	12th & 13th week	14th & 15th week	16th & 17th week	18th & 19th week	Total
12%	177	1077	1158	974	812	576	206	92	15	2	5089
13%	405	1599	1565	1684	1211	1212	790	665	189	1	9321
14%	572	1397	1421	1919	1968	1754	1273	431	46	169	10950

Moisture content of wheat	Number of progeny produced at 85°F. during: 1st week	2nd & 3rd week	4th & 5th week	6th & 7th week	8th & 9th week	10th & 11th week	12th & 13th week	14th & 15th week	16th & 17th week	18th & 19th week	Total
12%	263	727	1338	525	615	389	151	35	8	2	4053
13%	359	1100	1449	1136	1071	731	467	257	132	16	6718
14%	480	1135	1129	1377	1303	1242	900	425	8	8	8047

Table 10: -- Showing the number of progeny of granary weevil produced in 12, 13, and 14% moisture wheat at 70°, 75°, 80°, and 85° F.

Temperature	Number of progeny produced in: 12% Wheat	13% Wheat	14% Wheat
70° F.	2826	5517	3645
75° F.	3361	4436	2588
80° F.	5089	9321	10950
85° F.	4053	6718	8047

The decided increase in reproduction at 80° F. over that in 70° and 75° F., in all three moisture variant wheats is not entirely due to the increased temperature. It will be remembered that in the discussion of the results of the tests conducted at 70° and 75° F. it was stated that our supply of wheat used at the start of this series had been depleted and could not be replenished, necessitating a change to another lot, which contained a high percentage of "yellow berry". This latter wheat was used throughout the tests conducted at 80° and 85° F. It was shown in the discussion of the 70° and 75° F. series that this softer wheat was apparently more desirable for the breeding of the granary and rice weevil, and unquestionably is at least partly responsible for the increase in reproduction at 80° F.

In the case of the rice weevil the effect of both temperature and moisture upon reproduction is more pronounced and also more consistent. At a given temperature the amount of reproduction increases as the moisture content of the wheat is increased. And at a given moisture content, reproduction increases as the temperature is increased. Thus, at 80° F. the number recovered in 12, 13, and 14% moisture wheat was 9661, 10,267, and 13,551 respectively. At 85° F. the rate of reproduction increased up to the end of the 5th week, when a decrease in all moisture variants occurred owing to a sudden high mortality of the rice weevil adults in these cultures. See Report No. 8, page 25. This high mortality at the end of the 5th week was doubtless due to the naturally shorter life of the weevil at this temperature.

Table 11: -- Showing the biweekly reproduction of rice weevil in 12, 13, and 14% moisture wheat at 80° and 85° F.

Moisture content of wheat	Number of progeny produced at 80° F. during: 1st week	2nd & 3rd week	4th & 5th week	6th & 7th week	8th & 9th week	10th & 11th week	12th & 13th week	14th & 15th week	16th & 17th week	18th & 19th week	Total
12%	625	2390	2419	1429	1425	903	352	72	41	5	9661
13%	1122	2365	1766	1621	1382	1108	580	259	37	27	10267
14%	1581	2948	2441	1787	1667	1386	846	518	69	8	13551

Moisture content of wheat	Number of progeny produced at 85° F. during: 1st week	2nd & 3rd week	4th & 5th week	6th & 7th week	8th & 9th week	10th & 11th week	12th & 13th week	14th & 15th week	16th & 17th week	18th & 19th week	Total
12%	824	2051	1125	413	345	212	82	32	5	1	5090
13%	1115	1861	1713	537	445	308	199	156	93	9	6436
14%	1365	2573	1464	403	178						5983

Table 12: -- Showing the number of progeny of rice weevil produced in 12, 13, and 14% moisture wheat at 70°, 75°, 80°, and 85° F.

Temperature	Number of progeny produced in 12% Wheat	13% Wheat	14% Wheat
70° F.	4827	8692	10745
75° F.	4262	9244	12444
80° F.	9661	10267	13551
85° F.	5090	6436	5983

Effect of the Amount of Dockage on the Ability of Tribolium confusum to Survice and Reproduce in Wheat of Various Moisture Content*

The information herewith discussed is a continuation of the discussion under the same title on pages 32 to 33 of the 8th Report. Wheat with a moisture content of 9, 12, and 15% to which various amounts of dockage had been added was infested with 100 adult Tribolium confusum, and kept at a constant temperature of 80° F. At intervals of one week the various lots are examined and the percentage of survival determined. At the same time the number of pupae are removed and counted. In the previous report the period of time from the start of the series through the ninth week was discussed. In this report the discussion takes up the period of time from the tenth week through the nineteenth week, at which time the series was discontinued.

Table 13 summarizes the percentage of survival in the various lots, and in the last column lists the total number of pupae recovered for the 19 week period. In the lot comprised of whole clean wheat berries with a moisture content of 9%, the percentage of survival had dropped to 37% at the end of the nineteenth week. In all of the other dockage variant lots in the 9% moisture series very little difference is noted in the percentage of survival. A slightly lower percentage of survival occurred in the lot with 0.5% dockage, but this cannot be considered significant.

In the 12 and 15% moisture series, the survival in the dockage variants lots remained very high, with no significant variations. This indicates that although dockage is a major factor in survival in fairly dry wheat, it is not significant in wheat with a moisture content of 12% or more. Adult T. confusum are able to derive sufficient food from clean wheat, if the moisture content is high enough to enable them to gnaw through the bran coat. In these tests, feeding by T. confusum is confined to the endosperm of broken berries, and the germ of the whole wheat berry. After a period of nineteen weeks many berries have had the germ completely removed, and considerable feeding on the endosperm through the germ end of the berry is noted.

The presence of dockage, however, is a major factor in wheat from the standpoint of larval development. Tests on the effect of adult oviposition and egg hatching have shown that both may take place in an atmosphere of complete dryness. Although no tests have as yet been conducted to determine whether the adults will lay eggs in dry wheat, we do know that they will lay eggs in dry flour, and it seems reasonable that they would also lay in dry wheat. The fragile newly hatched larvae are apparently unable to gain sufficient food from the dry whole wheat berry, and are therefore dependent upon the finely ground dust or flour "milled" as a result of adult feeding. This fact is fairly definitely established by a study of the weekly summary of pupal recovery.

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* Reported by R. T. Cotton and J. C. Frankenfeld.

Table 14 lists the weekly recovery of pupae from the various dockage lots of the three moisture variant wheats. It will be noted that in the lots of 9% moisture wheat which was free of dockage at the start of the tests reproduction was delayed three weeks as compared to the other lots which contained dockage. It was not until the adults had "milled" sufficient flour, that the young larvae were able to develop.

In all three moisture variant wheats, the number of pupae recovered increased with the increased amount of dockage present in the wheat. This is not so pronounced in the 15% moisture series in the lots containing the smaller amounts of dockage. But in lots containing 2% or more dockage, the number of pupae recovered increased greatly as the amount of dockage was increased. The large number of pupae recovered in the clean wheat of the 15% moisture series is undoubtedly due to the easy "milling" quality of this high moisture wheat.

Another interesting fact presents itself from a study of those reproduction records. In all of the moisture-dockage variable lots, greatest recovery of pupae occurred during the sixth to tenth weeks in which these series of tests were in progress. After the tenth week there was a gradual dropping off of pupal recovery, until by the nineteenth week it was negligible for a number of the lots. This is particularly noticeable in the 9 and 15% moisture series. While this is also true of the 12% moisture series, it is by no means as pronounced. Just what the cause may be is as yet not determined and offers several new leads which require further investigation.

Table 13: -- Survival and reproduction of T. confusum in 9, 12, and 15% moisture wheat with varying percentages of dockage at 80° F.

Rearing medium	Percentage of survival after: 10 Weeks	11 Weeks	12 Weeks	13 Weeks	14 Weeks	15 Weeks	16 Weeks	17 Weeks	18 Weeks	19 Weeks	No. of progeny
9% Moisture Wheat											
Clean whole wheat berries	90	86	82	78	74	70	62	51	42	37	19
Same plus 0.5% dockage	94	93	92	89	89	89	88	87	86	85	13
" " 1.0% "	95	95	95	95	95	95	93	92	91	91	153
" " 2.0% "	91	91	91	91	88	88	88	88	88	88	233
" " 4.0% "	92	92	92	92	91	91	91	91	91	89	411
" " 8.0% "	93	93	93	93	93	93	92	90	88	88	700
12% Moisture Wheat											
Clean whole wheat berries	98	98	98	98	97	97	97	97	97	97	157
Same plus 0.5% dockage	97	97	97	97	97	97	97	97	97	97	211
" " 1.0% "	96	96	96	96	96	96	95	95	95	95	359
" " 2.0% "	98	98	98	98	98	98	98	98	97	97	453
" " 4.0% "	94	93	93	93	93	93	91	91	91	91	591
" " 8.0% "	93	93	92	92	92	92	80	77	77	77	718
15% Moisture Wheat											
Clean whole wheat berries	97	97	97	97	97	97	97	96	96	96	286
Same plus 0.5% dockage	97	97	97	97	97	97	95	95	95	95	249
" " 1.0% "	93	92	92	92	92	91	91	91	91	91	261
" " 2.0% "	98	98	98	98	98	98	97	97	97	97	319
" " 4.0% "	98	98	98	98	98	98	98	98	98	98	519
" " 8.0% "	93	93	93	93	93	93	93	93	93	93	895

Table 14: -- Showing the number of pupae of T. confusum from weekly examinations of 9, 12, and 15% moisture wheat with ranging percentages of dockage at 80° F.

Date	Number of pupae recovered in: * 9% Wheat in Lot No. 1	2	3	4	5	6	* 12% Wheat in Lot No. 1	2	3	4	5	6	* 15% Wheat in Lot No. 1	2	3	4	5	6
5/25/43:	0	0	0	0	0	0	0	2	2	11	4	18	8	2	3	13	17	31
6/ 1/43:	0	4	1	2	5	0	13	14	50	41	58	75	25	32	35	44	70	161
6/ 8/43:	0	3	28	25	46	1	26	39	60	66	88	113	41	60	61	66	90	175
6/15/43:	4	2	46	63	109	50	22	29	51	54	94	125	37	51	57	62	108	157
6/22/43:	4	3	29	55	95	198	14	15	29	52	86	79	48	45	54	55	53	89
6/29/43:	4	0	36	46	75	129	13	21	22	41	74	84	34	31	31	36	65	90
7/ 6/43:	4	0	11	21	35	96	20	14	22	38	35	59	44	16	8	19	26	54
7/13/43:	2	0	0	11	17	60	7	15	18	24	27	36	22	6	3	8	25	37
7/20/43:	0	0	0	1	9	32	9	17	9	11	16	13	6	1	2	5	13	23
7/27/43:	0	0	0	3	1	38	3	10	19	21	24	21	5	0	2	5	21	18
8/ 3/43:	0	0	0	1	5	23	1	12	22	18	18	25	3	1	0	1	10	11
8/10/43:	0	1	2	1	2	16	12	7	23	22	23	33	8	0	0	2	6	8
8/17/43:	0	0	0	2	5	12	4	2	10	17	8	5	1	1	0	0	6	7
8/24/43:	0	0	0	1	3	12	9	3	16	16	12	13	3	1	4	3	7	20
8/31/43:	1	0	0	1	4	33	4	11	8	22	24	19	1	2	1	0	2	14
Total	19	13	153	233	411	700	157	211	359	453	591	718	286	249	261	319	519	895

* Note: Lot No. 1 = Clean whole wheat berries
2 = Same plus 0.5% dockage
3 = " " 1.0% "
4 = " " 2.0% "
5 = " " 4.0% "
6 = " " 8.0% "